ATTACHMENT 1.2

ESTIMATES OF PUBLIC EXPOSURE AND RISK FROM APPLICATION OF ABLATION MINING IN THE SUNDAY MINE

PREPARED FOR BLACK RANGE MINERALS
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This assessment was performed to respond to the Colorado Department of Public Health and Environment 's (CDPHE) letter to Black Range Minerals of 13 August 2016 in which CDPHE requested that Black Range Minerals provide:

An evaluation of potential risks to the members of the public and the environment from the AMT operation, and from any potential incidents associated with the AMT operation.

1.0 Historical Data on Public Exposure from the Operation of the Sunday Mine

In accordance with the requirements set forth in 40 CFR 61.24, the former operator of the Sunday Mine submitted annual compliance reports to the USEPA for the years 2008, 2009 and 2010. The reports for these years were reviewed (Dennison Mines 2009, 2010, 2011) which provided estimates of public exposure from radon released from a number of vents of the Sunday mine complex during each year. Under 40 CFR 61.22, emissions of radon-222 to the ambient air from an underground uranium mine shall not exceed those amounts that would cause any member of the public to receive in any year an effective dose equivalent of 10 millirem (mrem) per year. Further, 40 CFR 61.23(a) provides that compliance with this emission standard shall be determined and the effective dose equivalent calculated by the US EPA computer code COMPLY-R. The maximum public doses reported for each of these three years to the maximally exposed member of the public (nearest residence about 6500 meters distance) were 0.5, 7.5 and 0.7 mrem respectively.

The US EPA's COMPLY-R reference model (USEPA 1989) was used for assessing the dose due to radon from mine emissions. For the year 2010, EPA's regulatory air dispersion code AERMOD (USEPA 2004) was also used to estimate atmospheric dispersion. A summary of emissions data and dose estimates extracted from the annual compliance reports to the USEPA for the years 2008, 2009 and 2010 is presented in Table 1. In all three reports, the operational circumstances were simply reported as "Annual ore production rate greater than 10,000 tons+". A typical mine vent (e.g., Topaz 1) at which radon release rates were measured is depicted in Figure 1.

Table 1: Sunday Mine NESHAPS Compliance Summaries – Annual reports for the years 2008, 2009 and 2010

Year	# of Vents Active and Monitored	Total Curies Released	Max Dose to Member of Public - Annual Basis (mrem /yr.)
2008	10	180	0.5
2009	16	2800	7.5
2010	10	1800	1.7

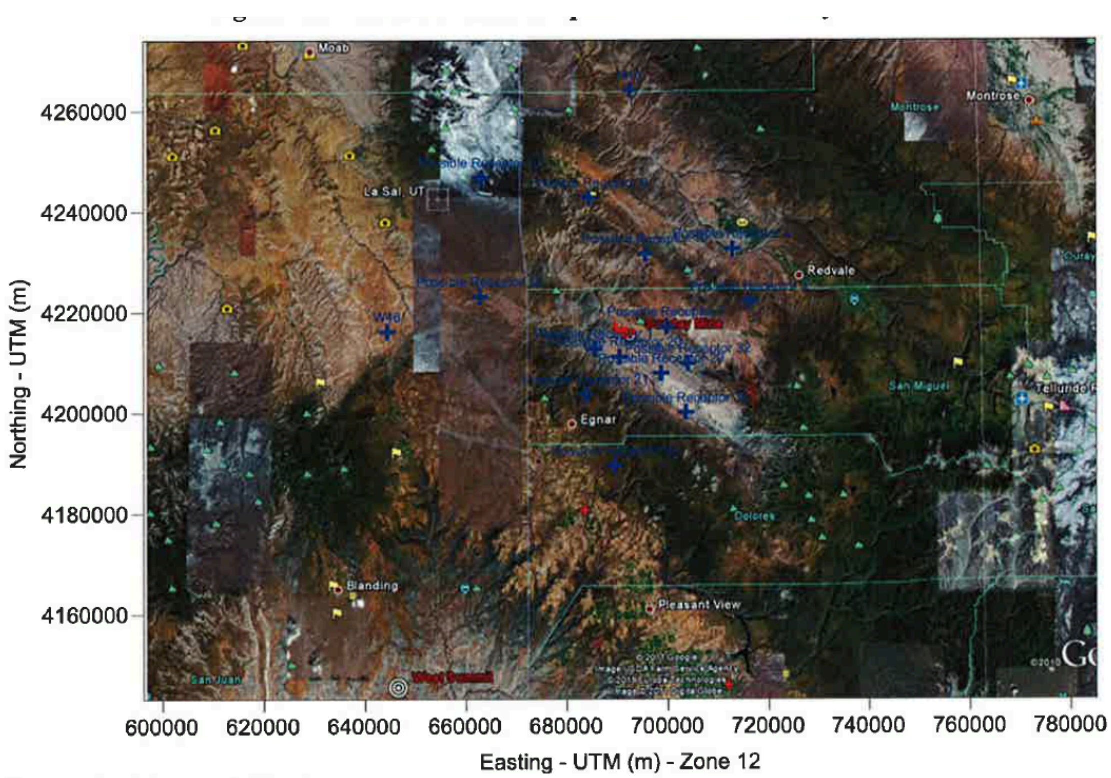
Figure 1: Sunday Mine Topaz # 1 Vent, Circa 2009

More detail and analysis was available for the compliance report for 2010. The results of this analysis for a number of public receptor locations is reproduced from SENES (2011) and depicted in Table 2 and Figure 2.

Table 2: Public Exposure Estimated for the Sunday Mine Complex, 2010

Receptor	Description	2010-Emissions-5months Dose mrem/year-Flat
R1	Possible Receptor 26	0.078
R2	Possible Receptor 20	0.400
R3	Possible Receptor 21	0.100
R4	Possible Receptor 1	0.700
R5	W48km	0.100
R6	Possible Receptor 15	0.200
R7	Possible Receptor 12	0.075
R8	Possible Receptor 8	0.079
R9	N48km	0.027
R10	Possible Receptor 10	0.065
R11	Possible Receptor 4	0.026
R12	Possible Receptor 3	0.040
R13	Possible Receptor 7	0.400
R14	Possible Receptor 32	0.300
R15	Possible Receptor 29	0.300
R16	Possible Receptor 33	0.200

Figure 2: Sources and Receptors for the Sunday Mine Dose Estimation From Radon Emissions in 2010 (From SENES 2011)



Notes: Red Colour in the Middle - Sources
Blue Crosses – Receptors

Dose estimates from the COMPLY-R and AERMOD models indicate that the dose due to radon to the maximally exposed receptor in 2010 was about 0.7 mrem / year resulting from the 5 months of operation of the Sunday mine complex during that year. The mine was active only through the period January – May 2010. However, it should be noted that the COMPLY – R results are historically considered conservative and will overestimate dose, largely from conservatism in the air dispersion modeling. Accordingly the 0.7 mrem / year at the R4 location (Table 2) is likely to be an overestimate. Similarly, the 0.5 and 7.5 mrem results for the years 2008 and 2009 respectively would also be considered an overestimate.

2.0 Implications for Use of Ablation Mining in the Sunday Mine

2.1 Radiological (Radon) Effluent Releases Expected from the Ablation Process

As discussed in greater detail in Section 3.0 of SHB 2016a, ablation is primarily an aqueous process. Similarities with radon emission from uranium mill tailings are considered relevant here since within the various stages of ablated material, all progeny are present in a sandy, moist (or water slurry) matrix. The emission of radon from uranium tailings has been studied and modeled for many years (EPA 1986, Nielson and Rogers 1986, Rogers et al 1984, Schiager 1974). Because of the very low diffusion of radon through water (as compared to partially air-filled unsaturated tailings pores), the diffusion of radon through water-covered tailings has been argued to be effectively zero (e.g. Chambers 2009). The EPA has previously assumed zero radon emissions from ponded areas of uranium tailings impoundments (e.g. EPA 1986).

Accordingly, very little radon would be expected to be evolved anywhere within the ablation process (mix tank through super sack loading of the ablated product with 15 % moisture) with the exception of the ablation units themselves. These are a special case as discussed below. However, in general, relative to the large surface areas of relatively dry ore in conventional mining operations which provide the "sources" for radon evolution and ultimately radon released through ventilation systems in effluents, the radon "source term" associated with the ablation mining process is expected to be small.

The water spraying on the ore in the ablation units would be expected to evolve most of the radon that is within the pore spaces of the matrix and that which becomes dissolved in the water from mixing with the ore. Rost (1981) demonstrated the ability of spray aeration to remove radon from well water at private homes in Maine. A one-stage aeration system achieved 75.7% radon removal efficiency. It was assumed that the rate of removal of radon from tailings pond sprinkler systems is similar to the removal rate of radon from spray aeration system described in Rost 1981 (See Chambers 2009).

Accordingly it is assumed that 100% of the radon contained in the pore spaces of the mineral grains at that time within the ablation units is released during the ablation spraying process. These units will be contained and enclosed and locally vented if necessary for worker protection (See SHB 2016a, Section 4.0) and would be expected to be the major source of radon in effluents from the ablation process. However, this radon "source term" would be expected to be a relatively small contributor to the overall source term released into the mine from walls and stopes within the conventional mining areas and as traditionally released to the atmosphere through existing mine vents (See Dennison Mines 2008, 2009 and 2010).

It is also recognized that some radon evolution into the ablation room will occur at the front end of the process from the dry ore prior to contact with water in the mixing tank. However, this ore is relatively of very low grade with an average of 0.25 % as compared to circumstances in Canadian underground mines with ore grades typically > 4-5 % average and as high as 20%. See the companion report, Section 3 of SHB 2016b.

2.2 Estimate of Public Dose From Normal Operation of the Sunday Mine Today

Regarding implication for the operation of the Sunday mine today, these circumstances of physics in combination with the public exposure estimates documented from previous operations of the Sunday Mine are instructive. Considering results for all three years of operation and for which compliance reports were available (Dennison Mines 2009, 2010, 2011), it is indicated that the Sunday mine has historically easily complied with the 10 mrem / year limit. It is also noted that the nearest candidate residences are at a considerable distance from any mine vent that would be used today. (> 6500 meters; approximately 4 miles). However, based on actual measurements of radon emission from all active mine vents that will be performed during operations, engineering / design adjustments can be made that will ensure compliance to the 10 mrem / yr. limit as may be necessary (increase vent / stack heights, use of "high tops" on vents, charcoal beds for radon capture, etc.). Accordingly, the maximum exposure to an actual member of the public from operation of the Sunday mine with ablation mining will be ≤ 10 mrem / year.

2.3 Risks of Accidents and Off Normal Operations

No reactive, explosive or otherwise toxic or hazardous materials are used in the ablation process. Only uranium ore and water is used. Accordingly, other than traditional and common accident risks associated with almost any industrial activity (e.g., electricity, slips, trips, falls, etc.), the only credible "accident" or "off normal" condition would be loss of fluids and/or slurries from containment within vessels. Since the operation takes place within an existing uranium mine, loss of radioactive material (ore) would be contained within the mine. Process areas that involve production and transfer of the ablation slurry concentrate, although still at a relatively low grade of ore (approximately 1-2 %), will be bermed and sumped as necessary to contain any spillage and facilitate recovery as necessary.

Each component of the system from the crusher through the AMT modules, separators, filters, and haulage truck loading will be monitored from within the control shack location of the Ablation Room. Conveying and feed systems from the crusher to the AMT mix tank will be equipped with load cells and adjustable speed motors to allow operator control and monitoring of the ROM mass feed rates. Load cells, pressure gauges, flow meters, and adjustable valves will allow for operator monitoring and control over water and slurry volumes and flow rates through the remaining portions of the system. The operator will be in control of each system component and based on the system monitoring devices will be capable of shutting any or all system components down at any time. In the event of a pipe or tank breach system components containing fluids will have secondary containment basins incorporated to capture and control the leak prior to system adjustments or shutdown.

3.0 Conclusions

Historical assessments of radon releases and public exposure had been performed by the previous operator of the Sunday mine in accordance with US EPA requirements for the years 2008 – 2010. Results indicated emissions and associated doses were well within EPA public exposure limits. Given the aqueous nature of the ablation process, evolution and subsequent emission of radioactive particulates and radon gas are expected to be lower than in conventional uranium mining. Accordingly, it is fully expected that dose to the public from application of the abalation technology is expected to be well below the US EPA limit (40 CFR 61.22) of 10 mrem/ yr. Additionally, since no reactive, hazardous or toxic chemicals are used in the ablation process (ore and water only), no credible accidents have been identified that could result in an abnormal condition resulting in releases of radioactive or other hazardous materials to the environment. Any spillage of ore, slurries or water will be contained within the mine. Continuous monitoring of operational parameters will ensure expedited response to and arresting of such events with a minimum of fluid or material loss that can readily and safely be remediated.

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